

REMARKS

Claims 1-23 are pending in the present Application. Applicant amended claims 1, 17, and 18, and added new claims 21-23. All amendments are supported by the specification.

Claim Objections

The Examiner objected claims 18 and 19 because of the following informalities:

Claim 18 recites the limitation “the switching LC resonator” in line 6. There is insufficient antecedent basis for this limitation in the claim. Claim 19 inherits the same.

In response, Applicant deleted “the switching LC resonator” and added “the resonant circuit”, which has proper antecedent basis.

Claim Rejections - 35 USC § 112

The Examiner rejected claim 17. The Examiner stated:

The examiner does not understand what the applicant means by: “the auxiliary power device is not coupled into the DC link lines.” The phrase “not coupled into the DC link lines” is especially confusing. Additionally, the applicant positively claimed, in claim 1, that the auxiliary power device is coupled between the DC link lines. This further confuses the claim limitations. Therefore, claim 17 is not given any patentable weight.

In response, Applicant notes that embodiments of “DC link lines” include DC link lines 150 in paragraph [0017] as well as items 150 in FIG. 1, which are voltage rails, coupling AC-to-DC converter 110, resonant DC link 120, and DC-to-AC converter 130.

Claim 1 recites:

“...the auxiliary power device is connected between the DC link lines...”

Some corresponding embodiments are illustrated in FIG. 1, where auxiliary power device 122 is not connected in series with, or into either of DC link lines 150, but instead it is connected between the two DC link lines 150.

The prior art is described in paragraph [0006] as:

“A particular feature of the above-described converters is that the auxiliary power device of the resonance of the DC link is placed into the power line. Such topologies cause a power loss by the load current, while the DC link voltage is at a nominal voltage level.”

Such coupling, or placing, a power device in series with, or into a (single) DC link line can be seen e.g. in FIG. 1 of the ‘685 patent (SC1 and SC2), as well as in FIGs. 3,4, and 6 (D) and FIG. 8 (SR) of the 793 patent, leading to losses.

Embodiments of the present invention avoid these losses by not connecting the auxiliary power device in series with, or into any of the DC link lines, but between the two DC link lines.

With this additional clarification, claims 1 and 17 clearly do not contradict each other. To capture this aspect more clearly, Applicant amended claim 17 to recite:

“17. (Currently amended) The converter of Claim 1, wherein:
the auxiliary power device is not coupled in[[to]] series with any one of the DC link lines.”

Finally, Applicant added new claims 21 and 22, which capture the above descriptions in an alternate manner as follows:

“21. (New) A converter circuit, comprising:
an AC-to-DC converter, comprising a plurality of first power devices;
a resonant DC circuit, comprising at least one auxiliary power device;
a DC-to-AC converter, comprising a plurality of second power devices; and

a positive DC link and a negative DC link, coupling the AC-to-DC converter, the resonant DC circuit, and the DC-to-AC converter, wherein
the auxiliary power device is coupled between the positive DC link and the negative DC link;
and
the resonant DC circuit is operable to clamp a voltage between the positive and the negative DC links.

22. (New) The converter of claim 21, wherein
the auxiliary power device is not coupled in series with any one of the positive DC link and the negative DC link.”

Claim Rejections - 35 USC § 102

The Examiner rejected Claims 1-3, 5-9, 11-17, and 20 under 35 U.S.C. 102(b) as being anticipated by Divan (US 4,730,242). The Examiner states:

Divan discloses a converter circuit, comprising: an AC-to-DC converter (S1-S6), comprising a plurality of first power devices (S1-S6); a resonant DC link (figure 7), comprising at least one auxiliary power device (113); a DC-to-AC converter (S7-S12), comprising a plurality of second power devices (S7-S12); and DC link lines (85, 86), coupling the AC-to-DC converter, the resonant link, and the DC-to-AC converter, wherein the auxiliary power device (bipolar 113 and diode S) is coupled between the DC link lines. The transistors are bipolar with diodes in parallel. The power devices are coupled pair-wise. The AC-to-DC converter comprises at least one of three first arms and simple rectifiers, generating an essentially DC voltage. First terminals coupled to corresponding first arms, the first terminals operable to receive AC power from an AC power source

In response, Applicant draws attention to a feature of embodiments of the present application.

Divan describes a problem of converters, arising from voltage stress. The voltage stress problem is illustrated by voltage spike 73 in FIG. 8, which can be 2-3 times higher than the operating voltage. In real terms, voltage spikes can reach 800 or even 1000 Volts. Such high voltages lead to heating problems and require the application of high voltage

rating power devices. Of course, high voltage rating power devices require larger chip area and lead to increased costs.

Applicant describes the same problem in the Background section and points out that clamping the operating voltage is a possible solution to voltage stress.

Correspondingly, the polarity of auxiliary power diode 124 enables Applicant's resonant DC link 120 to clamp the converter voltage. Therefore, resonant DC link 120 has the additional function of clamping the converter voltage, besides its resonating function. This clamping function is extensively described in the introduction as well as captured in claim 19.

The importance of the clamping function of DC link 120 can be appreciated as follows. Secondary power devices 132-1, ... 132-6 of DC-to-AC converter 130 can operate at lower voltages with the clamping action of DC resonant link 120, than without this clamping action, thus reducing voltage stress on the secondary power devices. Reduced voltage stress ensures that power devices with lower voltage ratings can be utilized as secondary power devices in the present invention, reducing heating, chip area, and cost.

In contrast, Divan's diode S of the "switching device 113" in FIG. 7 has the opposite polarity than the corresponding auxiliary power diode 124 in corresponding auxiliary power device 122. The polarity of the corresponding diode in all the related FIGs. 1, 2, 4, 5 is the same as in FIG. 7. Therefore, Divan's embodiments are not able to clamp the converter voltage.

In order to capture this difference, Applicant amended claim 1 to recite:

"...wherein ...the resonant DC link is operable to clamp an operating voltage of the converter."

With this amendment, claim 1 clearly recites a novel and important feature over the prior art, making claim 1 allowable.

The importance of clamping the voltage and its consequence for the voltage ratings can be further appreciated as follows. In various embodiments, Divan creates the resonant action by switching on and off power devices 101-106, or 87-92, instead of switching a self-standing power device, as power switch 113 of FIG. 7 of Divan, or power device 122 of the present application. In particular, the embodiment of FIG. 6 does not even have a power device equivalent to power switch 113 and thus equivalent to power device 122 of the present application. Instead, the entire resonant action is carried out by power devices 101-106 and 87-92. Correspondingly, the power devices 101-106 and 87-92 have to have high voltage rating.

In contrast, because of the clamping function, the secondary power devices 132-1, ... 132-6 of the present application inherently can have a lower voltage rating. The general benefits of voltage clamping have been described in the Background section and were captured in claim 19. Purely by way of example and not to restrict the specific values, without clamping the operating voltages can be as high as 800 or 1000 Volts, whereas in circuits with clamping the corresponding voltages can be in the 400-500 Volts range.

The implications of clamping on the voltage ratings is captured in new claim 21:

“23. (New) A converter circuit, comprising:
an AC-to-DC converter, comprising a plurality of first power devices;
a resonant DC link, comprising at least one auxiliary power device;
a DC-to-AC converter, comprising a plurality of second power devices; and
DC link lines, coupling the AC-to-DC converter, the resonant link, and the DC-to-AC converter, wherein
the auxiliary power device is coupled between the DC link lines; and
the secondary power devices have a voltage rating lower than the voltage output by the AC-to-DC converter.”

The Examiner rejected claim 14. The Examiner states:

Claim 14; Divan discloses a resonant capacitor (84); a diode (S); and a switch (113); coupled between the DC link lines and parallel with each other.

In response, Applicant notes that claim 14 depends from allowable claim 1 and is therefore allowable itself.

Claim Rejections - 35 USC § 103

The Examiner rejected claims 4 and 10 under 35 U.S.C. 103(a) as being unpatentable over Divan in view of Lee et al (US 5,633,793). The Examiner states:

Claims 4 and 10; Divan discloses the claimed subject matter in regards to claims 3 and 9 supra except for the power diodes being coupled across the power transistors comprises a first power diode being coupled between a source and a drain of a MOSFET first power transistor.

Lee et al teaches that each bridge switch of a converter and rectifiers has an anti-parallel diode associated therewith; and it is understood that these anti-parallel diodes may be either discrete components or the body diode in the case of an active switch such as a MOSFET.

Therefore, it would have been obvious to one having ordinary skill in the art at the time the invention was made to modify Divan to incorporate power diodes coupled between a source and a drain of a MOSFET in order to utilize the current carrying characteristics of MOSFETs as switching devices.

In response, Applicant notes that claims 4 and 10 depend from allowable claim 1 and are therefore allowable themselves.

Furthermore, Lee describes power device D in FIGs. 3, 4, and 6 and SR in FIG. 8, all connected into the main voltage rail, or DC link line, instead of coupling. Also, there is no teaching in Lee that it would be useful to move the power devices out of the main voltage rail. Therefore, combining Lee with Divan would create a converter, which does not recite the following limitation of claim 1:

“...the auxiliary power device is coupled between the DC link lines; and the resonant DC link is operable to clamp an operating voltage of the converter.”

Finally, there is no explicit teaching to combine these references in either of them. Without a teaching to combine, it is inappropriate to combine references according to the Manual of Patent Examining Procedures.

The Examiner rejected claims 18 and 19 under 35 U.S.C. 103(a) as being unpatentable over Divan in view of Lauw et al (US 5,559,685). The Examiner states:

“Claims 18 and 19; Divan discloses a resonant capacitor (C), comprising parasitic capacitors of the power devices; an inductance (L), coupled in parallel with the auxiliary power device, the inductance forming a resonant circuit with the resonant capacitor; and a second capacitor (C_p).

However, Divan does not disclose the resonant DC link comprises: a first capacitor coupled in series with the auxiliary power device.

Lauw et al teaches coupling a switch (S_{C1}) in series with a first capacitor (C_C), in parallel with an inductor (L_R) in parallel with a resonant capacitor (C_R) in order to clamp the link voltage to maximum voltage during non-zero segments of each link voltage pulse.

Therefore, it would have been obvious to one having ordinary skill in the art at the time the invention was made to modify the resonant DC link of Divan to include a first capacitor in series with the auxiliary switch as taught by Lauw et al and to couple the inductor in parallel with the auxiliary switch and first capacitor and have a second capacitor in series with the resonant circuit in order to clamp the link voltage to maximum voltage during non-zero segments of each link voltage pulse as taught by Lauw et al.”

In response, Applicant notes that claims 18 and 19 depend from allowable claim 1 and are therefore allowable themselves.

Further, Lauw describes converters, where the power devices of the DC link are coupled “into the DC link lines”. For example, power devices SC1 and SC2 are visibly coupled into the corresponding DC link lines. Therefore, Divan, alone or in combination with Lauw, does not recite the following limitation of claim 1:

“...the auxiliary power device is coupled between the DC link lines;”

Finally, Lauw's circuit cannot clamp the voltage either, because it does not employ a diode, corresponding to auxiliary power diode 124 of the present application, or equivalent circuit elements. Therefore, Divan, alone or in combination with Lauw, does not recite the following limitation of claim 1:

"...wherein ...the resonant DC link is operable to clamp an operating voltage of the converter."

For all these reasons, claims 18 and 19 are allowable.

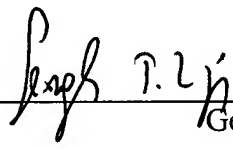
CONCLUSION

In light of the above remarks and with the above amendments, Applicant respectfully submits that all pending claims are in condition of allowance and therefore their allowance is requested. If any of the claims require further clarification or discussion, the undersigned is readily available at (415) 772-1200.

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